Expected ambient noise levels in different land-use areas

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ABSTRACT

The planning-stage prediction of environmental noise impact at a regional level, for both stationary and stochastically varying noise systems, is impeded by an absence of independent benchmarking for expected ambient noise levels in those areas.

This paper presents a retrospective review of historical records of ambient noise measurement carried out between 1990 and 2015. The records were sorted into classifications based on the land area usage at the time. The findings aim to assist development of a benchmark for ambient noise based on land usage, consolidated into statistical parameters, and includes a discussion of the associated variances.

The data is analysed to develop a method for prediction of levels that could reasonably be expected for different land area uses, including variance. The objective of the prediction is to facilitate effective high-level planning, enabling the estimation of magnitude of noise impact likely to arise from a major infrastructure or changing land-use development project in differing land use sectors within a region.

1 INTRODUCTION

This paper discusses background noise levels likely to be experienced in areas of different land area uses. The information presented in the paper has been compiled as part of a larger research project and responds to the guideline noise impact assessment methods documented by the New South Wales Environment Protection Authority (EPA). These methods are long-standing however have been complicated by recent changes to Australian Standard AS 1055 (Standards Australia, 2018) and by changes to the applications to which some aspects of the EPA policy documents may be applied. The availability of an independent benchmark for background noise levels, reported to the public as a part of many development proposals, has been eroded by the changes to AS1055 and this is aggravated by the increasing use of a background noise assessment threshold. The data also provides a benchmark to compare criteria used in the NSW Noise Policy for Industry (EPA, 2017, Part 2).

2 BACKGROUND NOISE

Background noise refers to a specific metric determined by statistical analysis of ambient noise level sampling at a specific location. The background noise level, $L_{A,90,T}$, refers to the tenth percentile of a data sample obtained over a specific measurement period (T) and is a principle that has been in use since 1980 and prior. The most common intervals are, probably, 15 minute and 1-hour sample periods, from which it is obvious that between 24 and 96 samples can be obtained for any given day of measurement. Data reduction is necessary to determine a suitable assessment metric.

The regulatory approach adopted by the EPA in NSW (EPA, 2017, 2.2) is to determine a day and night background noise rating level, being similar to but not identical with the $L_{A,90}$ mentioned above. The noise rating level is deemed generally to be the 5th percentile value from the array of measured $L_{A,90}$ levels obtained within an area of interest, over a period deemed to be free of any contribution of noise from a source for which impact assessment is to be carried out. Appropriate background noise levels are determined for relevant periods – daytime weekday, night weekday, daytime weekend, night weekend etc. Where interference from unrelated and/or non-typical noise is encountered, surrogate background noise levels are frequently obtained from nearby, or deemed-equivalent, locations. A further qualification in the EPA approach is that a lower limit threshold is applied to a calculated noise rating level, whereby quieter areas are assigned a lower limit noise rating level in place of the measured values. A consequence of this approach is that each site assessment is unique with verification by benchmarking of the reported findings now commonly unavailable.

Table 1: Land noise area categories (LNC) and land area uses

LNC[1]	Land Area Uses[2]	AS 1055 Category[3]	AS 1055 Description	ÈPA NPI[4] classification	EPA NPI Description
0	Acoustically Pristine	N/A		N/A	
1	Rural	R1	Negligible transportation	RU1-primary production	Dominated by natural sounds; little or no road traffic, sparse settlement
				RU2-rural landscape RU4-primary production small lots R5-large lot residential E4-environmental living	
2	Suburban	R2	Low density transportation	RU5-village	Local traffic, intermittent flows, evening noise levels defined by natural environment and human activity
				RU6-transition R2-low density residential	
3		R3	Medium density transportation, some commerce or industry	R3-medium density residential	
				E2-environmental conservation E3-environmental management	
	Urban			R1-general residential	Aggregate sound of many unidentifiable, mostly traffic and/or industrial related sound sources
4		R4	Dense transportation, some commerce or industry	R4-high density residential	
				B1-shop top housing B2-local centre B4-mixed use	
5	CBD	R5	Very dense transportation, in commercial districts or bordering industrial areas		
6	Industrial	R6	Extremely dense transportation, within predominantly industrial areas		

NOTES:
1. LNC identifies a Land Noise Category based on the Land Area Uses identified in column 2. Note that there is some overlap across the table.
2. Land area uses are generic land use descriptions
3. Categories listed in column 3 and descriptions in column 4 refer to the Noise area categories described in recently superseded issues of AS 1055.
4. The EPA planning classifications and descriptions summarised in Table 1 are those cited in Standard Instrument – Principal Local Environmental Plan, New South Wales Government, version 15 August 2014.

3 LAND AREA USES

Research into ambient noise levels has been carried out using measurement survey data compiled between 1995 and 2017, at site locations primarily in the eastern areas of NSW and southern Queensland. The data was then examined using linear model regression to determine predictive formulae for the statistics of ambient noise. The data were classified using categories for land area uses similar to those documented by the EPA and by previous editions of AS 1055 (Standards Australia, 1997), marginally expanded to include a category for acoustically pristine land.

The respective descriptions given in precis in Table 1 from both AS1055:1997 and the EPA Noise Policy for Industry (EPA,2017, Table 2.3) suggest that, while there is some overlap, reasonably good correlation shows the intent of both documents. A possible exception is the EPA R1-general residential land zoning.

It is evident from Table 1 that neither the Australian Standards nor NSW policy documents contemplate the preservation of Acoustically Pristine land, nor the preservation of very quiet land. Recently published World Health Organisation Guidelines [WHO,2018] do recommend the preservation of quiet areas as a guiding principle for noise policy, but have restricted issuing guideline noise levels to areas relating to human health and, therefore, occupied land areas only.

4 DATA ANALYSIS

This paper presents a retrospective analysis of ambient noise measurements carried out between 1990 and 2015. The records used were data for which the measurement sites could be sorted into classifications based on the land area usage at the time.

1. Data comprised statistically based $L_{A,fast}$ sound pressure level records, generally determined over intervals of 15 minutes however a small number of 5 minute duration samples were included.
2. Data was analysed to determine a mean background noise level ($L_{A,90}$) against land usage and time of day (TOD) for the standard periods of daytime (07:00-18:00), evening (18:00-22:00) and night (22:00-07:00). The variance of the mean background noise level values was determined, together with predictive relationships for the main statistical parameters for the period based on the background level for that period.
3. The data for LNC number 6 was excluded from the analysis. In addition to an absence of sufficient reliable data, intrusive noise is not generally a consideration of noise management policies for these areas.

Linear regression analysis derived the model described in Equation 1 to predict the expected mean value for a typical 15 minute period background noise level:

$$L_{A,90} = 6.5\,(LNC) + TOD + 27.4\text{dB} \qquad [R^2=0.94] \qquad (1)$$

where

$L_{A,90}$ is the mean 15 minute $L_{A,90}$ calculated for the average of day, evening and night period averages
LNC is the Land Noise Category Number, an integer from 0-5, from Table 1,
TOD is an adjustment for time of day, from Table 2,

and

To which allowance for random data variance may be included as discussed below.

With the exception of LNC number 0 (zero) land, for which Table 2 shows that modelling using equation 1 overestimated the mean day/evening/night $L_{A,90}$ by 4dB, Equation 1 produced mean expected land use area $L_{A,90}$ levels within +/-3dB of the measured levels. A logarithmic model was found to achieve a superior fit (R^2=0.98) and an improved correlation (modelled mean $L_{A,90}$ within +/- 2dB of the measured mean $L_{A,90}$) for <u>all</u> land areas. However, the quantity of available survey data for LNC=0 land was limited. While further surveying may justify a more complex model, the simplicity of a linear model is recommended at this stage.

Table 2: Mean value L_{A90} and TOD parameters vs Land Category Number, dB

Land Noise Category (LNC)	N, sites	n, samples	TOD Day	TOD Eve	TOD Night	Overall Measured Mean	Modelled Mean
0	1	442	+3.2	+0.7	-3.8	23.3	27.4
1	8	2911	+2.5	+1.3	-3.8	37.0	33.9
2	13	29619	+2.0	+1.4	-3.4	41.7	40.4
3	10	12033	+1.6	+0.7	-2.3	50.1	46.9
4	22	20570	+1.8	+1.0	-2.8	51.2	53.4
5	26	17902	+2.7	+0.9	-3.6	58.7	59.9

The linear model shows that raising the category of land usage by one level corresponds to an increase to the expected average background noise level ($L_{A,90}$) of 6.5dB. Within each category, time-of-day variation ranged generally from +3dB(A) daytime to -4dB(A) at night. Time-of-day (TOD) parameters summarised in columns 4 to 6 of Table 2 are the difference between the averages of the data on a time period basis and average of the three (D,E,N) periods represented by the 7th column of Table 2.

Variance and its effect on the value expected from a random measurement survey of a land area is important. Table 3 sets out the observed standard deviation, in dB, of each land use area dataset and shows that, overall, the standard deviation applicable to the expected mean level finding of such a survey, and to the predictions using Equation 1, is 6dB(A). In statistical terms, a 90-percent confidence interval for the measured mean of a dataset having a standard deviation is 6.0 is +/-9.9 dB(A). That is, if an impact assessment is based on a lower bound of the expected background noise – e.g. the 5th percentile of the range of the $L_{A,90}$ as represented by the background noise rating level used in the EPA documents – a confidence interval lower bound should be added to the results of Equation 1, producing expected levels 10dB lower than those reported in columns 7 and 8 of Table 2.

Table 3 shows that the inclusion of variance is likely to be more numerically significant to an analysis than the choice of land category number. One conclusion from this is that ambient noise is so variable that it is not possible to allocate an expected background noise level considering only a land area use. This conclusion is reasonable for the examination of a specific site study, however when benchmarking a planning proposal at a concept stage site-specific survey data is unlikely to be useful, or even relevant. The range of likely noise levels implied by equation 1 including variance can provide a useful context to site specific survey data.

For the design of a simulation study considering the range of impact outcomes likely for a large area land use planning study, however, Table 3 shows that the inclusion of variance is highly desirable, for both the likely source levels enabling comparison with a range of likely background noise conditions within the area of impact. It is of more immediate relevance to consider how the observed variance should be considered when comparing these findings with the criteria tabled in the EPA Noise Policy for Industry. Using the statistics of a normal distribution, Table 3 shows that the lower bound of a 90 percent confidence interval will be 10 decibels lower than the overall means observed in this study. This parameter can be compared with the tables of Rating Background Noise Level determined as the 5th percentile survey LA90 values, for which guideline criteria are included in Table 2.3 of the EPA document.

Table 3: L_{A90} Standard Deviation vs Land Noise Category

LNC	Day	Eve	Night	Mean
0	5.0	8.3	4.5	5.9
1	7.4	8.8	8.7	8.3
2	5.1	4.8	5.8	5.2
3	4.2	4.5	5.2	4.6
4	5.7	6.2	6.7	6.2
5	5.9	6.4	7.4	6.6
Overall mean Standard Deviation	5.4	6.2	6.4	**6.0**

Ambient noise varies stochastically and is commonly described using statistical noise level measurement units, of which the $L_{A,90}$ is one. The relationship between statistical noise levels and the $L_{A,90}$ for the same period is described in Equation 2:

$$L_{A,N} = L_{A,90} + K_1, K_2, K_3 \text{ , dB} \quad (2)$$

where

$L_{A,N}$ is a statistically based noise level (parameter N=0, 1, 10, 50 or 100, and L_{Aeq})
$L_{A,90}$ is determined from Equation 1, and
$K_{1,2\&3}$ are $L_{A,N}$-L_{A90} parameters from tables 4, 5 and 6 for Time of Day and Land Noise Category.

The values reported in Tables 4 to 6, giving ambient noise level statistical parameters, were derived by computing the difference between the mean level of the statistical parameter ($L_{A,N}$) for each time-of-day period and land noise category and subtracting the mean overall LA90 level for the same noise category.

Table 4: K_1 $L_{A,N} – L_{A,90}$ parameters for Daytime

LNC	$L_{A,max}$	$L_{A,1}$	$L_{A,10}$	$L_{A,50}$	$L_{A,90}$	$L_{A,min}$	$L_{A,eq}$
0	33.7	22.0	13.5	5.1	0.0	-3.5	12.0
1	26.7	16.3	8.5	3.2	0.0	-3.2	7.2
2	25.3	17.7	10.0	3.2	0.0	-1.8	2.3
3	25.5	17.4	10.5	4.2	0.0	-3.1	7.9
4	20.8	12.7	7.5	3.1	0.0	-2.9	5.2
5	20.5	12.6	7.4	3.4	0.0	-3.3	5.1

Table 5: K_2 $L_{A,N} – L_{A,90}$ parameters for Evening

LNC	$L_{A,max}$	$L_{A,1}$	$L_{A,10}$	$L_{A,50}$	$L_{A,90}$	$L_{A,min}$	$L_{A,eq}$
0	24.7	14.4	8.7	2.8	0.0	-3.9	6.7
1	20.2	12.9	7.7	3.3	0.0	-3.6	5.6
2	20.9	15.1	8.3	2.4	0.0	-1.6	5.9
3	24.8	16.5	9.6	3.5	0.0	-2.7	7.1
4	20.4	12.7	7.4	3.1	0.0	-2.9	5.2
5	20.1	12.4	7.3	3.3	0.0	-3.2	5.1

Table 6: K_3 $L_{A,N} – L_{A,90}$ parameters for Night

LNC	$L_{A,max}$	$L_{A,1}$	$L_{A,10}$	$L_{A,50}$	$L_{A,90}$	$L_{A,min}$	$L_{A,eq}$
0	22.0	10.6	5.6	1.6	0.0	-2.8	4.2
1	24.2	14.5	9.3	3.5	0.0	-3.2	7.4
2	23.3	13.0	7.5	2.6	0.0	-2.9	6.4
3	26.4	14.8	8.1	2.6	0.0	-2.7	7.0
4	27.2	16.1	9.2	3.2	0.0	-3.0	7.9
5	27.9	16.8	9.9	3.3	0.0	-2.9	8.5

An alternative presentation of expected ambient sound level, based on this source data, for the different land noise category areas, data analysis using reverse transformation sampling allows the reconstruction of the typical sound pressure level distribution within those areas. These level distributions based, derived from the mean statistical sound pressure levels for each category, are shown in Figure 1 for the case of sound pressure levels occurring at night and Figure 2 for daytime. The distributions in both figures are segmented as they have been derived from widely spaced sampling statistics and smoother curves would have been determined had data been sampled more regularly, say every 5th percentile. Notwithstanding, the relative modal characteristics, and the overall sound level overlap between adjacent categories, can be clearly seen.

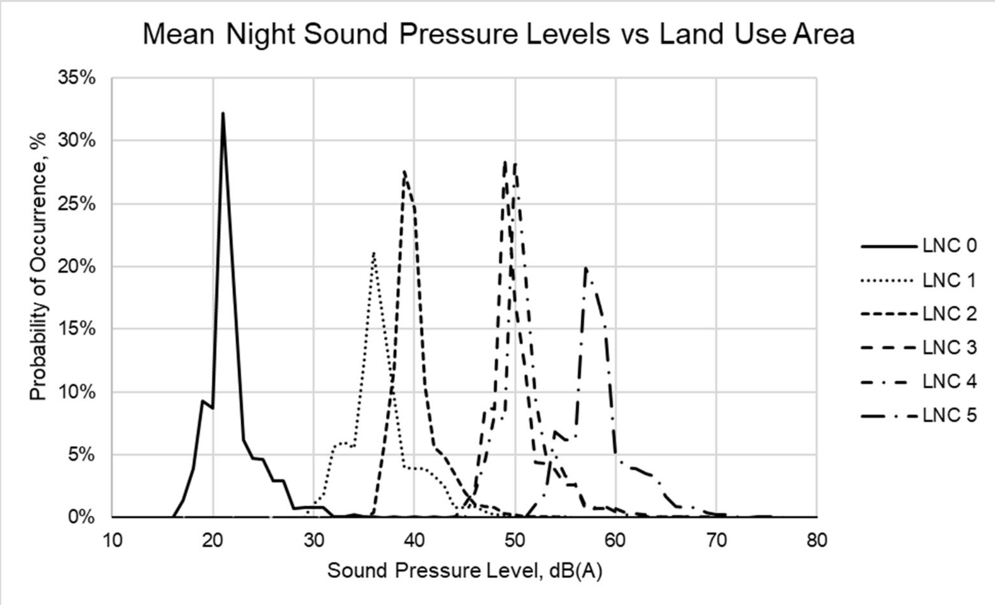

Figure 1: Noise level distributions at night

Among other characteristics, the relative daytime vs night time prominence of louder noise events in acoustically pristine areas (LNC 0) is evident, as is the progressive decline in prominence of louder events generally as the noise category trends from low values (pristine and rural) toward higher (CBD). These characteristics are also reflected in the inter-statistical indices summarised in Table 7.

Finally, Tables 8 and 9 set out comparisons of these analytical findings with the guideline assessment criteria documented in current NSW legislative policies issued by the EPA.

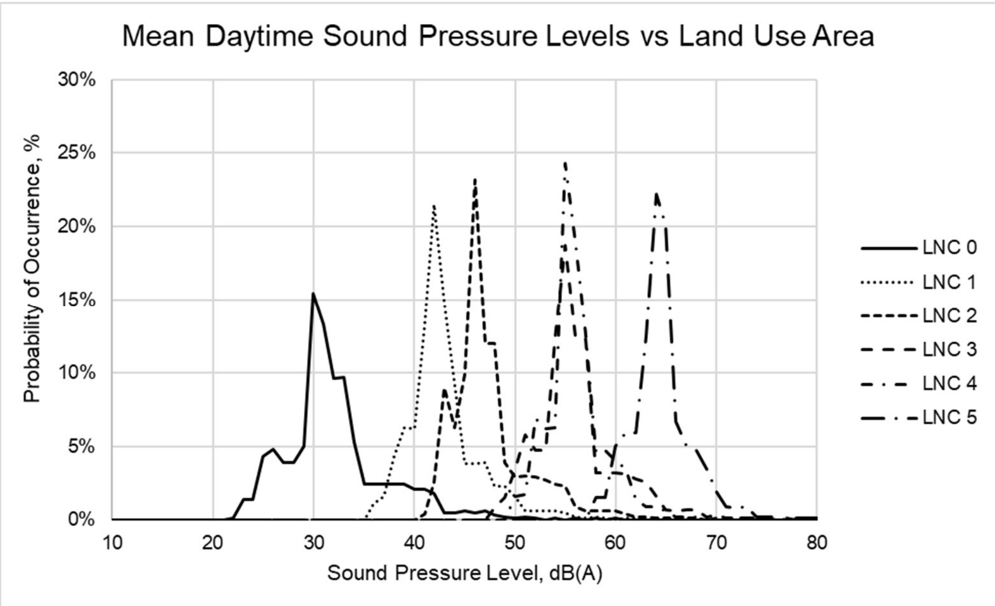

Figure 2: Noise level distributions daytime

Table 7: Mean Intra-statistical range for different land use areas, dB(A)

	$L_{A,max} – L_{A,min}$			$L_{A,1} – L_{A,90}$			$L_{A,10} – L_{A,90}$		
LNC	Day	Eve	Night	Day	Eve	Night	Day	Eve	Night
0	37.2	28.5	27.2	22.0	14.4	12.5	13.5	8.7	6.5
1	29.9	23.8	25.0	16.3	12.9	14.3	8.5	7.7	8.7
2	27.1	22.5	17.4	17.7	15.1	10.4	10.0	8.3	5.4
3	28.7	27.5	24.0	17.4	16.5	13.8	10.5	9.6	6.9
4	23.7	23.3	21.7	12.7	12.7	12.1	7.5	7.4	6.6
5	23.8	23.2	23.8	12.6	12.4	14.1	7.4	7.3	8.5

Table 8: Survey levels compared with guideline Noise Policy for Industry criteria, dB(A)

LNC	Land Type	L_{A90}[1]observed D/E/N[2]	L_{Aeq} observed D/E/N[2]	EPA NPI[3] Receiver Category	NPI[3] RBL[4] dB(A) D/E/N[2]	NPI[3] Amenity[5] L_{Aeq} D/E/N[2]
0	Acoustically Pristine	17/14/10	39/31/25			
1	Rural	30/28/23	47/44/40	Rural Res-idential	<40/<35/<30	50/45/40
2	Suburban	34/33/28	51/49/42	Suburban Residential	<45/<40/<35	55/45/40
3	Urban	42/41/38	60/58/53	Urban Residential	>45/>40/>35	60/50/45
4		43/52/48	48/4743			
5	CBD	51/50/45	66/65/61			

Notes:
1. L_{A90} refers to the lower bound 90% confidence of the observed mean.
2. D/E/N refers to day, evening and night period data.
3. Noise Policy for Industry Table 2.3.
4. Noise Policy for Industry 2017 rating background noise level.
5. Noise Policy for Industry 2017 amenity criteria for dwellings

5 DISCUSSION

Figures 1 and 2, showing the distribution in noise levels observed in different land use areas, are interesting as this data suggests there are four generally distinct noise category areas, being acoustically pristine land, rural and quiet suburban land, suburban and urban fringe land, and CBD land. The distribution in observed ambient noise levels shown in Figures 1 and 2 can be seen to be roughly 10 to 15 decibels apart. As noted earlier, industrial land has been excluded from this review.

Excluding acoustically pristine land, the categories do, in fact, roughly align with the categories for dwellings listed in the EPA Noise Policy for Industry (Tables 2.2 and 2.3, NPI, 2017).

The parameters set out in tables 4 to 6 demonstrate the different variances and variation in ambient noise observed in different land use areas. These are summarised in Table 7 using the raw survey data, which shows that as the land uses develop from acoustically pristine and rural to urban and CBD, the range in instantaneous daily noise level is compressed. Numerical simulation of statistical noise levels using inverse transformation sampling, Figure 3, shows why this should be expected. This compression of statistically based sound levels has implications when considering noise impact.

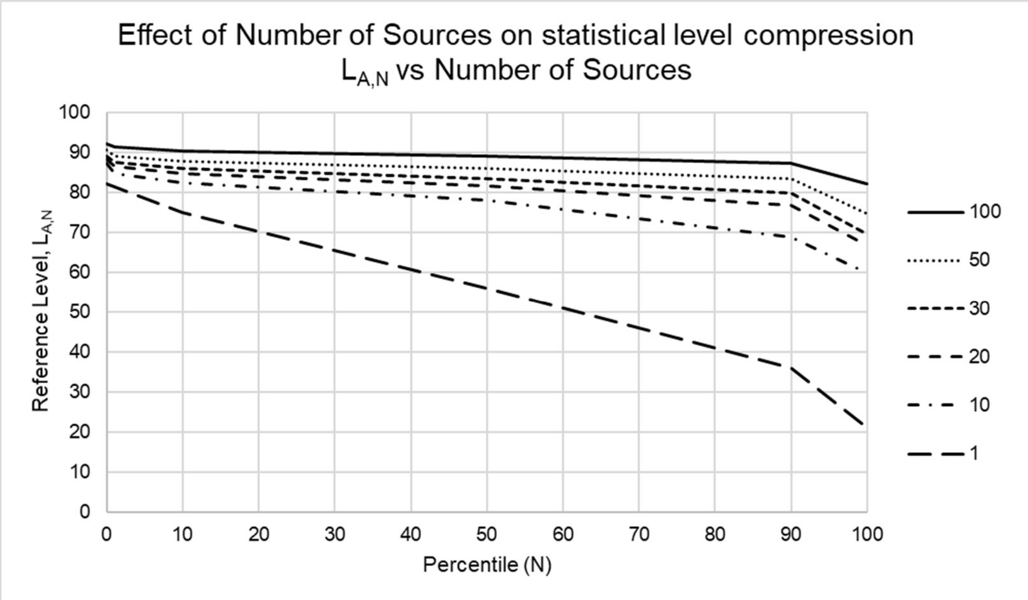

Figure 3: Statistical noise level compression

From a planning perspective, deletion of estimated average background sound pressure levels from the 2018 updated issue of AS1055 is unfortunate. Planning decisions and general policy development cannot be robust without consideration of the likely consequential changes to the acoustical environment, and the associated noise impact, for which physical measurement of existing conditions may be either impractical, irrelevant, or unnecessary. Further, where a report on a specific site study is prepared and circulated for comment, previous editions of the AS 1055 standard provided an independent benchmark to the study no longer able to be referenced.

Table 9 is an important summary drawn from this study and allows comparison with the information available to practitioners, planners and local authorities in both the recent update issue of Australian Standard 1055 (Standards Australia, 2018) and the Noise Policy for Industry (EPA, 2017). In both authoritative references, the absence of acoustically pristine land from comment is an obvious omission. Such land is an increasingly important National asset and warrants recognition at the least.

Notwithstanding this author’s opinion that the LAeq noise level does not reflect acoustical amenity, the difference between the observed average LAeq and the amenity criteria from the NPI, particularly land category 5 in Table 9, appears consistent with part 2.4.1 of the Policy referring to modifications to amenity levels in areas of high traffic noise.

Table 9 provides a context highlighting the significance of the instruction in Fact Sheet A1.2, and elsewhere of the Noise Policy for Industry, that

> *Where the rating background noise level is found to be less than 30dB(A) for the evening and night periods, then it is set to 30 dB(A); where it is found to be less than 35 dB(A) for the daytime period, then it is set to 35 dB(A).*

Areas where this study has identified background noise conditions likely to be affected by the EPA Policy instruction, are shown underlined and bold in Table 9. It is important to note that the EPA states (NPI, section 1.4) that the Policy is designed for “large industrial and agricultural sources” and it is evident that these activities are generally compatible with the EPA land usage descriptions of Table 8 for land noise categories higher than 3, and therefore unlikely to be compromised by the principle of an assumed background noise threshold. However, in section 1.1.1 of the Policy, prior to the clarification noted above from part 1.4, the policy states that "planning authorities can use the noise levels in the policy to inform decisions about the potential impacts of different types of development". This is likely to apply to future land use planning activities and to the affairs of local government, for which Table 8 shows that the use of an assumed threshold value to background noise is likely to lead to unsatisfactory outcomes if applied to decision making for Acoustically Pristine, rural and quiet suburban areas. As regards the proportion of land likely to be disadvantaged by such a principle, the statistics of this study suggest that 100 percent of Acoustically Pristine land, approximately half of rural land and at least some portions of quieter suburban areas would be compromised.

Table 9: Ambient Noise Levels observed compared with activity and traffic presence, dB(A)

LNC	Land Type	AS1055 Description[1]	EPA NPI Description[2]	L_{A90}[3] observed D/E/N[4]	L_{Aeq} observed D/E/N[4]	NPI RBL[5] dB(A) D/E/N[4]	NPI Amenity[6] L_{Aeq} D/E/N[4]
0	Acoustically Pristine			**17**/**14**/**10**	39/31/25		
1	Rural	Negligible transportation	Dominated by natural sounds; little or no road traffic, sparse settlement	**30**/**28**/**23**	47/44/40	<40/<35/<30	50/45/40
2	Suburban	Low density transportation	Local traffic, intermittent flows, evening noise levels defined by natural environment and human activity	**34**/33/**28**	51/49/42	<45/<40/<35	55/45/40
3		Medium density transportation, some commerce or industry		42/41/38	60/58/53		
	Urban		Dominated by 'urban hum'………. aggregate sound of many unidentifiable, mostly traffic and/or industrial related sound sources…heavy and continuous traffic flows…near commercial districts			>45/>40/>35	60/50/45
4		Dense transportation, some commerce or industry		43/42/38	58/57/53		
5		Very dense transportation, in commercial districts or bordering industrial areas		51/50/45	66/65/61		

Notes:
1. AS1055:1997.
2. Noise Policy for Industry Table 2.3.
3. L_{A90} refers to the lower bound 90% confidence of the observed mean
4. D/E/N refers to the day, evening and night period data.
5. Noise Policy for Industry 2017 rating background noise level.
6. Noise Policy for Industry 2017 amenity criteria for dwellings

6 RECOMMENDATIONS

This study has identified parameters associated with ambient noise level conditions likely to encountered in practice and has categorised the findings according to land area uses.

It is fundamental that any noise impact assessment report examining a planning proposal should identify existing ambient noise conditions within potentially affected areas and, ideally, should provide a context to those conditions. This will enable the various stakeholders to a development to make informed decisions. The information provided in this paper is likely to assist in providing that context.

The formal expansion, of the 2017 issue NSW Noise Policy for Industry, from the 2000 issue of the NSW Industrial Noise Policy, to include intensive agricultural premises, may warrant more careful consideration of intrusive noise impacts on surrounding areas than the Policy is likely to identify.

The recommendation that regulatory and planning authorities use the NSW Noise Policy for Industry, as a basis for considering impact from different types of development likely to fall within their jurisdiction, should be withdrawn. The policy is designed for specific industrial developments.

The strict limitations of the principle applying a lower limit threshold to an assessment of background noise levels solely in land areas to which the Noise Policy for Industry applies should be noted and publicised.

Legislative and regulatory consideration of means to identify and protect acoustically pristine lands from progressive contamination by noise arising from development is required.

REFERENCES

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